PROPAGATION ANALYSIS OF ROAD GUIDED WAVES BY RAY METHOD

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Introduction

With the development of land mobile communication, radio waves are now being used in everywhere around us. The propagation characteristics, however, are not necessarily well known in density built-up urban areas, especially on roads surrounded by buildings or obstacles when a transmitting antenna is located several meters above the ground[1]. Waves on roads are considered to be a sum of road guided waves such as multiple reflected waves from side walls of buildings and diffracted waves from edges of buildings. The same situation occurs in snowy regions where snow packs beside road construct a groove guide. It is important to investigate the radio propagation characteristics along groove guides to estimate the effect or influence on the total propagation. In this paper, a simple ray method is applied to examine the propagation characteristics of road guided waves, and then a comparison with the experimental results are shown.

Geometrical Optical Approach

Fig.1 shows the simplified cross section of a road to be considered here. Mediums beside road are assumed to be lossy dielectrics with relative dielectric constant ε_{r1}, and conductivity σ_1. Medium below the ground plane has material constants ε_{r2} and σ_2. In the analysis, a simple ray approach similar to that given by Kishimoto[2] is applied. That is, the field intensity at a receiving point may be expressed by the sum of a direct wave from a transmitting antenna, and multiple reflected waves which bounces on side walls and/or on the ground plane. For simplicity, transmitting and receiving antennas are assumed to be located in the z-axis.

A ray from a source point O to a receiving point P that bounces on side walls m times and on the ground n times, may be considered to come from image sources A(±m,-n) as shown in Fig.2. The number of reflections on the ground plane, n, is 0 or 1 for this problem. If a vertically polarized wave is radiated from a source point O, the wave will be attenuated and suffered phase shift by $Rm=R_h^{|m|}R_v^{|n|}$, where R_h and R_v are the Fresnel's reflection coefficients.

$$R_h = \frac{\tan\theta - \sqrt{\varepsilon_1(1+\tan^2\theta)-1}}{\tan\theta + \sqrt{\varepsilon_1(1+\tan^2\theta)-1}}, \quad R_v = \frac{\varepsilon_2\tan\phi - \sqrt{\varepsilon_2(1+\tan^2\phi)-1}}{\varepsilon_2\tan\phi + \sqrt{\varepsilon_2(1+\tan^2\phi)-1}} \quad (1)$$

where θ,ϕ are grazing angles for incident wave to side walls and to the ground plane, respectively.

$$\varepsilon_i = \varepsilon_{ri} - j\ 60\sigma_i\lambda \qquad (\lambda\text{:the free space wavelength}) \qquad (2)$$

Path length from image point A(m,-n) to a receiving point P is

$$l_{m,n} = \sqrt{l_{0,0}^2 + (ma)^2 + (nb)^2} \qquad (3)$$

Attenuation $L_{m,n}$ due to this length $l_{m,n}$ is given by

$$L_{m,n} = \frac{\lambda}{4\pi l_{m,n}} \qquad (4)$$

Also, phase difference from direct wave will be

$$\Phi_{m,n} = \exp[j2\pi(l_{0,0} - l_{m,n})/\lambda] \qquad (5)$$

When a $\lambda/2$ dipole antenna is used, the radiation pattern is given by

$$T_{m,n} = \frac{\cos(\pi/2\ \sin\phi)}{\cos\phi} \qquad (6)$$

Hence, the electric field from a image source A(m,-n) to a receiving point can be obtained by the following equation

$$E_{m,n} = R_{m,n}\ L_{m,n}\ \Phi_{m,n}\ (1.28\ T_{m,n})^2 \qquad (7)$$

The total field is the sum of these waves;

$$E = \sum_{n=0}^{1} \sum_{m=-\infty}^{\infty} E_{m,n} \qquad (8)$$

In a similar manner, the field strength can be calculated for the case of horizontally polarized wave radiated from a transmitting antenna.

Experimental results

In order to examine whether this simple method is applicable or not, we measured the electric field intensity along a groove guide. Fig.3 shows the experimental setup for microwave simulation. The lossy materials used were made of foaming phlystyrol combined with carbon, and have material constants ε_r=1.3, σ=0.17 S/m. A $\lambda/2$ dipole for transmitting antenna was located at one end of the guide, and a $\lambda/2$ dipole receiving antenna was moved along the center line (z-axis) of the guide. Fig.4 shows the comparison with calculated and measured results for horizontally and vertically polarized guided waves operating at the frequency of 12 GHz. It is seen that the field decays in proportion to the distance between antennas except for the near region. Fig.5 shows field distribution in the the x-axis(a) and y-axis(b) for a vertically polarized wave, measured at distances of 0.5λ, 9λ and 20λ from a transmitting antenna. Calculated results agree well with experimental data.

Conclusion

A simple ray method was applied to determine the propagation characteristics of road guided waves, and resulted in a good agreement with the microwave simulation. As a result, this method seems to be effective for practical use. However, further examinations will be required on the dimensional dependence both theoretically and experimentally.

References

[1] M.Kaji and M.Nishio,"UHF-band short-range radio propagation in density built-up area", Technical Report on Antennas Propag., IECE of Japan, A.P84-25, 1984.

[2] H.Kishimoto,"Indoor radio propagation analysis by ray method", Technical Report on Antennas Propag., IECE of Japan, A.P76-62, 1976.

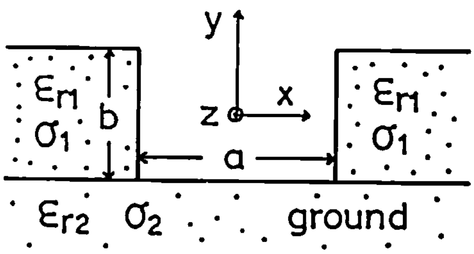

Fig.1 Cross section of a groove guide

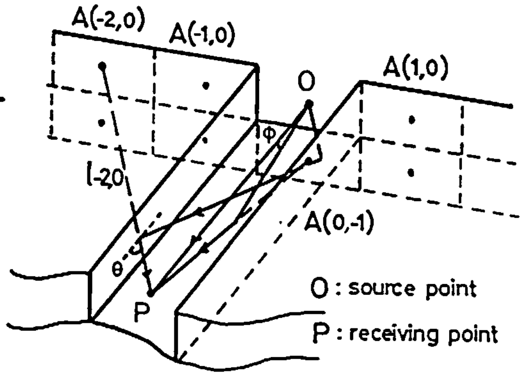

Fig.2 Ray paths and image sources

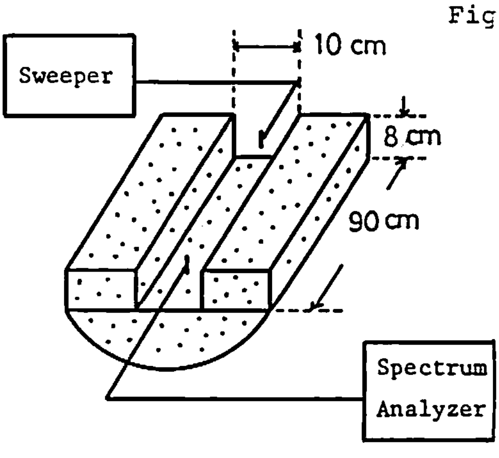

Fig.3 Experimental setup

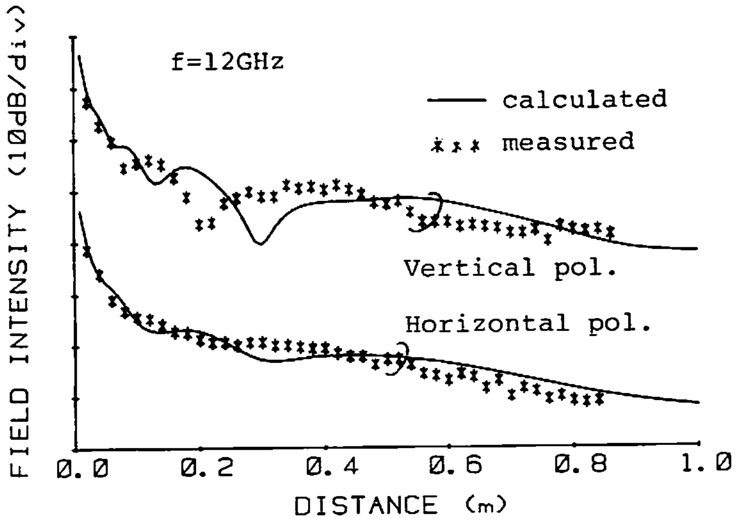

Fig.4 Electric field intensities in the z axis of the guide.

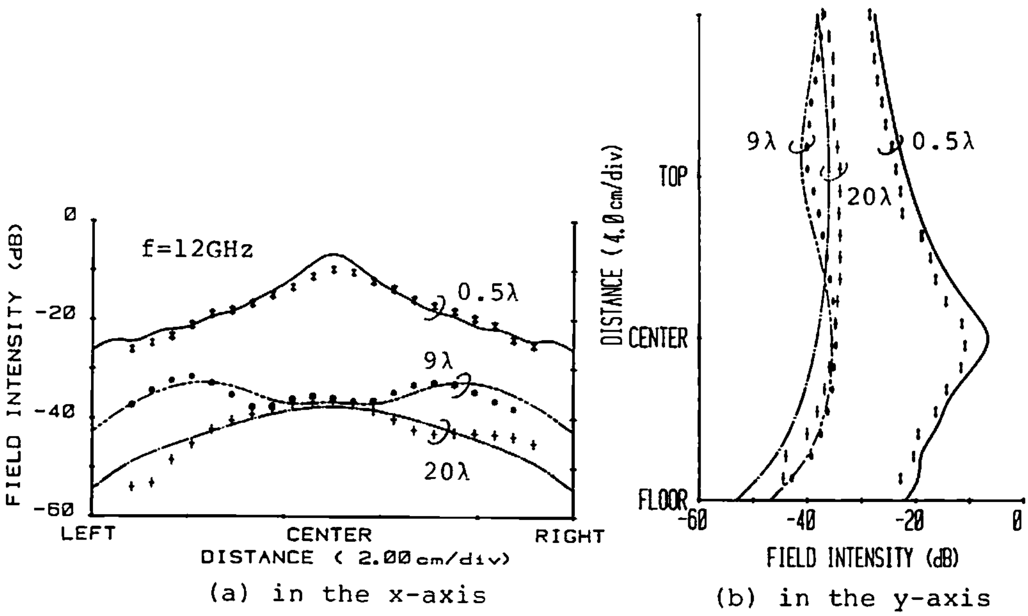

Fig.5 Field distribution in the cross section.